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# Certification

This is to certify that the foregoing translation of patent EP667596(A1) entitled **"Method to be used for the representation of text and graphics on color screen devices"** was made from German to English by a competent translator well acquainted with both languages, and that, to the best of our knowledge and belief, it is a true and complete rendering into English of the original document.

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Method to be used for the representation of text and graphics on color screen devices

The invention relates to a method used to represent text and graphics on a color visual display unit, which comprises a raster with a pre-defined number of image elements (pixels) in the x direction and the y direction, and an image repetition memory with a color bit depth of $i$ bits, wherein the characters to be represented are downloaded from memory in digital outline format wherein the raster points lying on the outline of each character are determined by a scanning method. According to the invention, in order to obtain a better image quality, a brightness graduation is performed in that the rasterization and calculation of the character positions are carried out in a fine raster process, character by character, wherein every pixel of the screen raster is sub-divided into $m$ fine-raster pixels in the x direction and into $n$ fine-raster pixels in the y direction, where $m$ and $n$ are natural numbers greater than 1 and $m \times n \leq i$, and every individual character in the fine raster is converted into a bitmap coding. The bit values of the $m \times n$ fine-raster pixels in every screen raster pixel of every character are written - as a bit sequence - in the memory location of the particular screen raster pixel in the image repetition memory. In order to represent the image, every memory location of the image repetition memory is read out and the particular screen raster pixel is assigned a shade of gray that depends on the sum of the bit values of the read-out bit sequence, and then represented on the screen with an intensity that corresponds to the shade of gray.

The invention relates to a method used to represent text and graphics on a color visual display unit, which comprises a raster with a pre-defined number of image elements (pixels) in the x direction and the y direction, and an image repetition memory with a color bit depth of *i* bits per screen raster pixel, wherein the characters (letters, related graphic elements, and line drawing elements) to be represented are downloaded from memory in digital outline format, scaled, turned, and positioned to meet the text/image requirements, and the raster points lying on the outline of each character are determined using a scanning method (grid walk).

Visual display units represent characters and other graphics as dissected images. The image area usually contains 500 to 1,000 television lines, each of which consists of about 600 to 1,200 image points (pixels). Without limiting the general nature of this issue, in the following text we will assume that the length of the pixels (x direction) is set up in such a manner that it corresponds with the line spacing (y direction) and that one thus obtains quadratic image points (pixels). Every pixel can be assigned any color value, i.e., any graduation of brightness of the individual colors: red, green and blue; texts and graphics (e.g., CAD) are frequently shown in the visual image unit as a black-and-white representation; in this case, each color value corresponds to a shade of gray between white and black, which are produced by the uniform excitation of the color centers for red, green, and blue with an intensity corresponding to the desired shade of gray (brightness). For the sake of notional simplification, in the following text the black-and-white representation with graduated shades of gray will be examined as with any other color as a graduation of brightness. Thus, the term "shade of gray" will be used in the same sense as a "color brightness value."

At present, PCs, process computers, and mainframe computers are typically equipped with color display units (monitors) for communication and visual inspection. The display representation is controlled in the visual display unit by means of a special electronic circuitry (graphics board) in conjunction with a special driver (software). The graphics board contains, among other things, an image repetition memory, in which memory is reserved for every raster pixel; in the case of a color display, this memory has a depth of several bits designed for the encoding of a color. The information stored in the image repetition memory is periodically read out in the image repetition frequency – for example, 60 or 72 Hz – and the digital color information is converted to analog control for the sweeping and intensity of the three electron beams for red, green, and blue color signals. In the image repetition memory, the memory for one pixel usually has a depth of 6 bits, 32 bits, or more to encode the color of the pixel. The color is usually encoded using brightness values for the three basic colors of television – red, green, and blue (RGB). With 16-bit encoding, 5 bits correspond to red, green, and blue respectively, that is, to 32 color brightness values or grades. Furthermore, it is known that one can encode the colors in a varied design, so, for example, 5 bits can be reserved for gray tones or 10 bits can be reserved for green tones. Moreover, the color values can be stored, for example, in printer colors (yellow, magenta, cyan, and black - YMCK) to create the corresponding colors using re-coding tables. Such encoding tables are usually denoted with the English expression look-up table (LUT).

If one compares the quality of color reproduction on color displays with that of images printed by color laser printers, one perceives the quality of image reproduction as basically comparable. However, if one compares the quality of black-and-white text representation on displays with that of laser printouts, one will likely see a noticeable difference in quality. Texts appear on displays – particularly in small fonts as shown, for example, in Figures 4a ad b – as only barely legible. This problem is, of course, connected with the resolution of displays, which are typically four times lower than those of laser printers. However, this mainly stems from the fact that when observing color images – i.e., colors, particularly red – one does not need as great a resolution. With a common observation distance of 80 cm for the color displays of computer workstations, the resolution requirement for colors is about 75 dpi (dots per inch), while for black-and-white images (for example, texts or CAD graphics) it is about 175 dpi or more. This increased resolution need occurs particularly when we must discern thin lines in graphic representations and words in small fonts.

Since 1980, the manufacturers of computers and operation systems have been trying hard to raster characters from outline data for the reproduction on visual display units – usually black-and-white – to achieve maximum legibility and the best possible form of reproduction of the written image, which is then released to higher-resolution output devices such as laser printers or laser exposure devices. This quality level has been called "WYSIWYG" (what you see is what you get).

Various manufacturers have developed data formats for the storage and provision of characters and related graphic elements that are called intelligent digital outline formats. Characters are formed by black, flat lines whose outlines are described in a piece by piece fashion using short straight lines (vectors) or curve elements. Circular scales, sections of quadratic or cubic spline functions are mostly used as curves. In addition, these outline descriptions are equipped with hints and instructions for the execution of rasterization in order to avoid the so-called raster accidents. A raster accident may represent, for example, the rasterization of the letter *m* with its vertical elements of a different thickness as shown in the left example in Figure 1a, or the rasterization of a very thin line with exclusively white points as is illustrated in the left part of Figure 1b. In order to avoid such artifacts and randomness of rasterization, special instructions, for example, for (letter) stem control or drop-out control have been introduced. Using such hints and instructions, rasterization accidents can be avoided as shown in the right part of Figure 1a and Figure 1b for the above exemplary rasterization accidents. A detailed description of various intelligent outline formats and of the intelligent rasterization process can be found in the professional literature, for example, "Digital Schriften" [Digital Fonts] by Peter Karow, Springer Verlag 1992, Chapter 8, and in "Schrifttechnologie" [Font technology] by Peter Karow, Springer Verlag 1992, Chapter 7, wherein the further description of outline formats of characters and their rasterization are explicitly included in this disclosure. The aforementioned works also describe modern and often used font types, such as PostScript Type 1, TrueType and IKARUS formats.

The processing speed is one of the most important criteria for a scaling program that converts characters with an intelligent outline description, such as PostScript Type 1,

TrueType and IKARUS, into a bitmap image for visual display units. For example, with texts, it often happens that somewhere on the page a word or even only a letter is removed, after which the page must be displayed anew, exhibiting the change without any substantial time delay. In the common methods, we can distinguish four processing phases, which on average tend to take about the same time for a typical text processing operation with a normal font, such as Times Roman 12 pt font size:

1. Download fonts from a memory, de-compress, initiate management, load general parameters;
2. Evaluation of the instructions and creation of the outlines that are adapted to the desired raster (for example, 12 pt size for 72 lpi on the display) (grid fit);
3. Execution of the mathematical instructions on the curve and straight-line calculation and determination of the raster points, which lie on the outline (grid walk); and
4. Filling of the black pixels between two outlines (bit fills).

The result of this four-step process is a bitmap, which represents the rasterization of a letter, where the bit values 0 and 1 stand for white and black or vice versa, depending on the definition.

After the calculation of the letter position, which results from the text calculation performed in a device-independent text-coordinate system (in further text, the positions in this text-coordinate system are referred to as text coordinates) in a resolution of, for example, 2,400 lpi and units of 1/20 pt (one pt is the size measurement unit for fonts and equals about 0.351 mm (Didot point), this bitmap is then copied to the pertaining image repetition memory (video ram) to the relatively rough, and also rounded-off display position to which it corresponds.

Since the display point (pixels) take up a relatively large area, namely about 0.4 x 0.4 $mm^2$ to 0.25 x 0.25 $mm^2$ (about 70 lpi to about 100 lpi, lpi = lines per inch), we must accept the fact that the rasterization of the fonts will be rough and, especially for small fonts, insufficient with regard to their legibility. Furthermore, we must tolerate the fact that the letter widths are rasterized in full pixels, for which reason quite different character positions and distances are determined, which subsequently necessarily renders the overall appearance of the text line inferior. Also, in the y direction the characters are positioned with the accuracy of only a television line, which results in different text line distances in a text. In an analogous fashion, in CAD graphics the line thickness that on an A4 format paper has a line width of 0.2 mm, cannot be suitably represented on a typical display; this would require lines as thin as 0.05 mm.

In order to produce better quality text reproductions, it would be desirable to show the relative position of letters beside each other in a more accurate manner than is possible with units of 0.25 to 0.4 mm of length. It would also be desirable to show the position of the lines to each other in a more exact fashion than is possible with the pixel sizes on today's common visual display units. In terms of comparison, we should note that in typography – the book-printing art – one works with units of at least ¼ pt (about 0.1 mm). Since such an attenuation of the pixels or the raster size of visual display units is

too costly in several respects, we must look for other ways to improve the image quality of texts and graphics on visual display units with the resolutions that are currently common.

EP-A 0 132 456 discloses a method used to control the typesetting quality of electronic typesetting devices by showing the typesetting image on a monitor. The typesetting device contains the bitmap of a full page to be printed, with which a film is to be exposed and stored in a very fine rasterization. In order to allow one to check the typesetting image before the film is exposed, the complete bitmap of the page is read out and converted into a rougher raster for the monitor in that $m$ subsequent pixels of $n$ adjacent lines are merged, the average gray value of this $m$ x $n$ super-pixels is determined, and these super-pixels are then displayed as raster pixels on the monitor. However, such a method is not practical for the text representation on simple visual display units (of personal computers, for example) because first, a finely rasterized bitmap of a page to be printed must be prepared in specially designed processors (RIPs, raster image processors) in a time-consuming procedure, and only then can they be transferred back to the PC, which would result in overall unacceptable response times, because an interactive work requires a practically delay-free display on the monitor. Furthermore, with every change in the page, even the change in a single letter, would require a new preparation of the entire page in the fine raster and a new transfer into the display raster, which is impossible due to the limitations of processing speed.

The underlying technical task of this invention is to propose a method for the representation of characters and graphic elements on visual display units, which allows one to improve the legibility and image quality with the same display resolution as that of the common methods, and with a time delay that is acceptable for interactive applications.

This invention proposes a method for the black-and-white representation of text and graphics on a visual display unit, which comprises a display raster with a pre-defined number of image points (pixels) in the x direction and the y direction and an image repetition memory with a bit depth of $i$ bits per display raster image point (pixel), wherein the characters (letters, related graphic elements, and line-drawing elements) to be represented are downloaded from memory in a digital outline format, scaled, turned and positioned to meet the text/image requirements, and wherein the raster points that lie on the outline of each character are determined by means of a raster scanning method (grid walk), characterized in that the rasterization and the calculation of the character's position are performed in a character by character fashion for each individual character in the text or in the graphics in a fine raster, in which every pixel of the display raster in the x direction is sub-divided into $m$ and in the y direction is sub-divided into $n$ fine-raster pixels, where $m$ and $n$ are natural numbers greater than 1 and $m$ x $n \leq$ i, and every individual character in the fine raster is converted into a bitmap encoding,
the bit values of the $m$ x $n$ fine-raster pixels in every screen raster pixel of every character are written - as a bit sequence - in the memory of the particular screen raster pixel in the image repetition memory, and

in order to represent the image, every memory location of the image repetition memory is read out and the particular screen raster pixel is assigned a shade of gray that depends on the sum of the bit values of the read-out bit sequence, and is then represented on the screen with an intensity that corresponds to the shade of gray.

Using the method as designed by the invention, we can achieve (1) a better representation of individual characters, (2) a better positioning of the characters in a text line (in the *x* direction), (3) a better positioning of the text lines with respect to each other (in the *y* direction), and thus overall (4) a better legibility and true form of the text image or graphic parts.

A substantial advantage of the present invention is the fact that the display representation can be generated very quickly so that no disadvantage arises compared to the commonly used methods, which produce an inferior image quality (bitmap).

With these features, the method as designed by the invention is especially suitable for interactive applications in which the pages that are to be subsequently printed on high-resolution printers must be constantly changed and thus must not cause any noticeable time delays.

In the first step of the method designed by this invention, every required character is rasterized in a fine raster, in which every image point (pixel) of the display raster is *m* times subdivided in the x direction and *n* times sub-divided in the y direction so that *m* x *n* fine-raster pixels lie in every display raster pixel. Using its outline encoding process, every individual character is rasterized in the fine raster by a commonly used rasterization method; in this manner, the fine-raster pixels lie on the outline [of the character] (grid walk), wherein a bitmap representation is subsequently generated in the fine raster (bit fill). Thus, each involved pixel of the fine raster is assigned a bit value of 1 or 0 (for colors of red, green, blue or black-and-white).

In the next step, the bit values of the *m* x *n* fine-raster pixels in every screen raster pixel of a character are written - as a bit sequence - in the memory of the particular screen raster pixel in the image repetition memory.

In the subsequent step, in order to represent the image, every memory location of the image repetition memory is read out and the particular screen raster pixel is assigned a shade of gray that depends on the sum of the bit values of the read-out bit sequence, and then represented on the screen with an intensity that corresponds to the shade of gray.

In this manner, a part of the higher information content of the fine raster is taken over into the rougher display raster by determining the gray shade of every display raster pixel in dependence on the number of the filled (black) fine-raster pixels in it, and subsequently converted into the corresponding intensity of the pixel. The sum of the filled fine-raster pixels results simply from the sideways sum of the bit sequence, when 1 stands for black and 0 for white.

In an especially preferred embodiment of the invention, however, the sum of the filled fine-raster pixels and the gray shade are not determined by calculation from the bit sequence, but rather, a gray shade is assigned to every bit sequence by interpreting the bit sequence read out of the image repetition memory as an address and the pertaining gray shade with this address is read out from a look-up table prepared and stored in advance. This look-up table (LUT) technique allows one to perform a direct conversion of the fine raster in every display raster pixel into a shade of gray without any calculation steps. This step can be performed, for example, on the graphics board directly after the read-out from the image repetition memory without time loss and using a relatively minute electronic process.

This manner of using the image repetition memory by color displays has a number of advantages:

1. No additional memory for higher-resolution text sections and black-and-white graphics is required;
2. The look-up tables prepared in advance eliminate any time loss in displaying text or image representations in better resolution gray representation on color displays;
3. For texts and black-and-white graphics, the legibility and the perceived quality of representation are increased and generally comparable to that of laser printers;
4. The higher-resolution fine-raster image is available for electronic image enlargements or handling; this achieves a noticeable quality improvement for graphics programs with respect to fine positioning and fine retouching;
5. The graphics and text programs can rely on the display representation of a higher resolution corresponding to that of laser printers;
6. The higher resolution is beneficial not only for the representation of text, but also for the representation of line graphics in CAD programs. It is especially in the field of CAD applications, where the higher-resolution display of technical drawings is required in formats larger than DIN A3, when one wants to avoid using paper output for checks and corrections;
7. Firstly, the higher fine-raster resolution can be adjusted to that of a connected laser printer so that the information from the image repetition memory can be used directly for the printer output (screen shots), because no new interpretation of the page description and rasterization in the printer is required; secondly, this procedure allows one to use printers that are equipped with very little processing electronics (for example, printers without PostScript RIP).

In a preferred embodiment of the invention, the gray graduation (shades) is expressed in $(n \times m + 1)$ gray values of white and black and the gray values are represented by the sum of the bit values of the fine-raster pixels so that the gray values range in grades of 0, 1, ...., $n \times m$ from white to black (or vice versa). As a result, the gray value of a display raster pixel is determined by the relative share of filled fine-raster pixels contained in it, i.e., the gray value is proportional to the ratio of the entire area of the filled (black) fine-raster pixels to the entire area of the display raster pixel and, consequently, corresponds to an average gray value. However, other means of graduating the gray values can also be provided, especially in non-linear dependence on the gray value of the number of the filled fine-raster pixel.

In a preferred embodiment of the method, the fine raster of every display raster pixel is written into the image repetition memory by logically associating the bit sequence with the content of the memory location in the image repetition memory corresponding to this display raster pixel in a bit by bit process using the logical OR association. This ensures that when any two adjacent characters come very close to each other, the gray values in the intermediate space correctly superimpose, i.e., the gray value of a pixel of a first character, which is already written into the image repetition memory, is "added" to the gray value of a character that was processed later, and which reaches into the same display pixel.

However, the method as designed by the invention does not mean that we have to do without the visual display of colors. Depending on how fine the fine raster is selected and what bit depth the image repetition memory has, excessive bits can be used for a common encoding of the color of the display pixel, whose color will then be displayed on the pixel with the gray value (i.e., color brightness or intensity) that results from the equally stored fine raster.

It is useful to use 1 bit in every memory location as a flag bit to indicate whether color is stored in the usual manner (color mode) in the memory location or whether fine-raster pixels are stored in the memory location in the method as designed by the invention (fine-raster mode). In the latter case, the memory location content is first converted into a certain color intensity according to the invented method by determining the gray value.

With a bit depth of the image repetition memory of 16 + 1 bits, one can, for example, use 1 bit as the flag bit and subdivide the display raster into $m = n = 4$ fine rasters. In this case, no additional encoding of color is possible. If, on the other hand, we use an image repetition memory with 24 + 1 bits per display pixel, with an $m = n = 4$ fine raster and a flag bit we can still use 8 bits for color encoding.

The application of the invented method allows one to achieve an improved legibility and image quality without increasing the computing volume and thus the time required to create a display image. Using the present method one can achieve time savings since during the rasterization of the character we can eliminate step 2 (grid fit) of the above-described conventional method. An optimal fit of the character in the fine raster using intelligent raster techniques is not required because this fine raster is finer than that to be displayed and any rasterization accidents occurring on the fine raster level will only negligibly affect the quality on the level of the display pixel. This allows - especially if high processing speed for the image display is required – one to eliminate, in an advantageous manner, the intelligent rasterization process that uses instructions in outline format in order to save computing time.

According to another aspect of the invention, the method of the aforementioned type is characterized in that, before the beginning of a text display, only once are all characters of a text selected by the user rasterized into a fine raster, which in the x direction is *m* times finer and in the y direction *n* times finer than the display raster, where *m* and *n* are

natural numbers greater than 1 and $m \times n \leq i$, and all rasterized characters are converted into a bitmap encoding and stored in buffer memory,
for text or image display, the fine-rasterized characters are downloaded from the buffer memory according to the text or image requirements and by their position in the text or image, are transferred into a corresponding fine-raster position in the display raster,
the bit values of the $m \times n$ fine-raster pixels in every display raster pixel of every character are written - as a bit sequence - in the memory location of the particular display raster pixel in the image repetition memory,
for image display, every display pixel memory location in the image repetition memory is read out and the particular display raster pixel is assigned a shade of gray that depends on the sum of the bit values of the read-out bit sequence, and is then represented on the display with an intensity that corresponds to the shade of gray.

With the last invented method, the processing speed is further increased in that the letters of a desired text are rasterized in a fine raster and stored only once at the beginning and subsequently, every time they are needed in the text, they are simply retrieved and transferred into the corresponding text position to determine the gray representation in the display raster.

In the following text, we shall now explain the invention in a more detailed manner using the attached figures. The individual figures show:

Figure 1a:
Raster representations of a character, simply rasterized on the left, and rasterized on the right using an intelligent rasterization procedure with instructions (line thickness control);

Figure 1b:
Raster representations of a character, simply rasterized on the left, and rasterized on the right using an intelligent rasterization procedure with instructions (line maintenance);

Figure 2a:
Lines of the thickness of a display pixel with various gray values (original size);

Figure 2b:
The lines from Figure 2a in double enlargement;

Figure 3a:
Letter pairs with different gray values in the interstice (original size);

Figure 3b:
Enlargement of the letter pairs from Figure 3a:

Figures 4a and 4b:
Display of a multiple-line text in 9 pt using the Nimbus Roman fonts, displaying, for comparison, the text with a conventional procedure (Figure 4a) and in gray display (Figure 4b) on the same visual display unit;

Figure 5a:
Fine raster of the outer outline of the letter b;

Figure 6:
Letter b (turned by 90°) in run-length representation;

Figure 7:
The display of a letter in the fine raster that illustrates the calculation of fine-raster pixels falling under an $m$ x $n$ display pixel;

Figure 8:
Enlarged display of a letter resulting from the invented method in gray representation in the display raster;

Figures 9a and 9b:
The 16 different gray representations of the letter 'o' that are possible with the shift of the letter 'o' along the fine-raster pixels ($m = 4$, $n = 4$) always using one fine-raster pixel in the x direction and the y direction, where Figure 9a shows the original size on a typical visual display unit and Figure 9b shows an enlargement;

Figure 10:
Shows a display pixel with an $m = n = 4$ fine raster and a bit sequence corresponding to the matrix of the fine-raster bit values; and

Figure 11:
shows a flow diagram that illustrates the process of reading the memory location in the image repetition memory corresponding to the display raster pixel shown in Figure 10.

The invented method allows one to optically work with smaller pixels than those available on the visual display unit. In the process, the following physiological fact is utilized: With the naked eye, we perceive lines of the thickness of a typographic point (namely from 72 lpi) as being thinner if it is displayed as less black, that is if it is displayed as gray. We can notice this phenomenon in Figure 2a, where lines of the same thickness but with different gray values are displayed besides each other. For comparison, Figure 2b shows the image of Figure 2a but twice enlarged, In this comparison we can see that, depending on the gray value, lines appear thinner or thicker even if their actual thickness is the same.

Moreover, a black area appears to be already shifted if we add gray in one direction, for example, in the width of a television line. We especially perceive the distance of two letters already when only gray is inserted between them as can be seen in Figure 3a. The lighter the inserted point the more the letters appear to be separated from each other; Figure 3b shows the letter pairs from Figure 3a enlarged (and in a reversed order). The superimposed characters differ from each other only in the shifts in the fine raster that result in slightly different gray representations.

The difference between the conventional black-and-white display and the invented gray representation on a visual display unit is best appreciated if we observe the two variants of a multiple-line text on a visual display unit and compare their entire appearance. Figure 4a shows a multiple-line text created with a conventional method on a visual display unit, while when the same text is displayed using the invented method on the same visual display unit, it produces the image as shown in Figure 4b. We can clearly discern the improved legibility and the overall impression of an improved image quality.

Previous examinations on displays (Xerox, Tektronix in "Visual Fatigue and Operator Performance with DVST and Raster Displays", Proc. Of the Society for Information Display, Vol. 24, No. 1, 1983) have established that the examined subjects quickly tired when recognizing and fixing letters displayed in gray. Since the gray displays cause a partially blurred edge of the black letters' surface, the examined persons repeatedly tried to re-focus the letters in the subconscious assumption that the perceived image is not displayed sharply enough. However, when reading a real text we only rarely really "fix" the individual letters because we read a text in the so-called "saccades." Thus, it is natural for us to perceive the major part of the text only in gray. In this aspect also lies the phenomenon that gray displays of texts are synonymous with a more accurate, that is a higher-resolution display.

As an example, take a visual display unit with an area of about 1,000 x 1,000 pixels and a pure black-and-white representation. For the fine raster, an m-times fine sub-division is performed in the x direction and an n- times fine sub-division in the y direction, wherein in a preferred embodiment of the invention, $m = 4$ and $n = 4$. According to the experience gained in typography, in this manner we can achieve positionings with a precision of up to ¼ point (about 0.1 mm).

In the method as designed by the invention, the position of a character in the fine raster is determined, i.e., the character is laid into the fine raster and rasterized, wherein one of the known methods can be used for the rasterization process. In this process, simple rasterization methods can be used so that we can do without the usual use of instructions for outline formats of letters and the application of an intelligent grid fit. The result of rasterization in the fine raster is illustrated in Figure 5 on the example of the lower case of the letter b. The grid points that lie on the outline are determined using one of the known methods for a grid walk. The letter can first be displayed by means of the raster pixels that lie on the outline as is the case in Figure 5, or in a run-length encoding. With the run-length encoding, the character is recorded in lines by indicating, in every fine-raster line, the beginning raster pixel of every line consisting of at least one filled pixel in the x direction and the difference between the end raster pixel and the beginning raster pixel of the line, i.e., the run-length of units of pixels in the fine raster. Figure 6 illustrates the run-length encoding displayed for a lying b, where the run-lengths in every line are represented as a continuous line.

Subsequently, the fine-raster pixels that lie inside the outline are filled (bit fill) in order to obtain the bitmap of the character in the fine raster. Figure 7 shows the result, where the

letter 'b' is displayed in an m = n = 4 fine raster and, in addition, the display raster is also shown. The numbers indicate the number of the filled (black) fine-raster pixels in each particular display pixel, which will be later used to determine the gray value.

Figure 10 shows a single display raster pixel, which with m = n = 4 is sub-divided into 16 fine-raster pixels and, for example, corresponds to any display raster pixel from Figure 7. In the present example, white pixels are represented by the bit value 0 and the black pixel by the bit value 1. To store the display pixel, the matrix of 16 bit values of the fine raster is written as a bit sequence of 16 bits, as shown on the right side of Figure 10, and, furthermore, is written to the memory location that corresponds to the pertaining display pixel in the image repetition memory. When displaying the image, all display pixel memory locations of the image repetition memory are read out and the bit sequence of every display pixel is converted into a gray value. This can be performed either by means of a calculation, for example, by determining the sideways sum, or – and this is an especially preferred embodiment of the invented method - by interpreting the bit sequence as an address and, using this address, by reading out the pertaining gray shade from a look-up table prepared and stored in advance (look-up table). The storage of such a look-up table is possible because every sequence of 16 bits, which is just another form of writing a 4 x 4 matrix of the fine raster of the display pixel, can be imaged as a gray value for all possibilities. In the illustrated example with m = n = 4, the addresses are in a range from 0 to $2^{16} - 1 = 65535$ (the last address represents a display raster pixel that is completely filled with black fine-raster pixels). Thus, the look-up tale contains 65,536 entries with a total of 17 different values that represent the degree of filling of the display raster pixel with black fine-raster pixels. The sum of the fine-raster bit values in every display raster pixel can be interpreted directly as a gray value by displaying the sum 0 as white, $m \times n$ as black and the values between 0 and $m \times n$ as shades of gray from light gray to dark gray. The gray value is then proportional to the ratio of the black fine-raster pixels to the total number of fine-raster pixels in the display raster pixel, that is to an average gray value averaged over the black and white fine-raster pixels contained therein. However, the gray value can also be determined from the sum using a pre-defined dependence, in particular a less fine graduation of the gray values can also be applied, that is less $m \times n$ gray values. The result of a letter in gray representation is shown in Figure 8.

The procedure involving the use of a look-up table is once again illustrated in Figure 11. During a periodic read-out of the image repetition memory, the bit sequence (e.g., the bit sequence 0111111011001000 for the display raster pixel represented in Figure 10) is interpreted as an address and thus corresponds to the decimal number 32456. Under this address, a gray value has already been stored in the look-up table that corresponds to 9 black fine-raster pixels (cf. Figure 10). In a preferred embodiment of the method, the gray value is selected simply as equal to the share of black fine-raster pixels, thus in the present example 9/16, wherein a gray value 0 represents white and the gray value 1 represents black.

The described use of a look-up table eliminates all calculation steps because they must only be performed once in advance to fill the look-up table. In this manner, the method can be performed in a particularly quick fashion.

Figure 9a shows all 16 possible gray representations of the letter 'o' with $m = 4$ and $n = 4$ that result from a shift of the character in the x and y directions, each time by one fine-raster pixel. Figure 9b shows an enlargement of Figure 9a, from which it becomes evident that the gray representations of a character slightly differ depending on the position in the fine raster.

The invented method enables – without any increase in the processing time – a better legibility, in particular of fonts with a small point size and an improvement in the image quality. The invented method does not only increase the speed for the gray representation, but also the flexibility with respect to the font size, position, and possible turning of the characters.

The method can be applied to all fonts on displays (besides the Latin fonts, also, for example, to the kanji fonts) as well as to related graphic elements that are described by lines and curves, such as CAD representations.

The invented method is suitable for the text representation in modern operation systems, such as Mac OS and MS Windows.

Claims

1. A method used to represent text and graphics on a color visual display unit, which comprises a raster with a pre-defined number of image elements (pixels) in the x direction and the y direction, and an image repetition memory with a color bit depth of $i$ bits, wherein the characters to be represented are downloaded from memory in digital outline format, scaled, turned, and positioned to meet the text/image requirements, and the raster points lying on the outline of each character are determined using a scanning method (grid walk), **characterized** in that the rasterization and calculation of the character positions are carried out in a fine raster process, character by character, wherein every pixel of the screen raster is sub-divided into $m$ fine-raster pixels in the x direction and into $n$ fine-raster pixels in the y direction, where $m$ and $n$ are natural numbers greater than 1 and $m \times n \leq i$, and every individual character in the fine raster is converted into a bitmap coding,
the bit values of the $m \times n$ fine-raster pixels in every screen raster pixel of every character are written - as a bit sequence - in the memory location of the particular screen raster pixel in the image repetition memory, and
in order to represent the image, every memory location of the image repetition memory is read out and the particular screen raster pixel is assigned a shade of gray that depends on the sum of the bit values of the read-out bit sequence, and then represented on the screen with an intensity that corresponds to the shade of gray.

2. A method used to represent text and graphics on a color visual display unit, which comprises a raster with a pre-defined number of image elements (pixels) in the x direction and the y direction, and an image repetition memory with a color bit depth of $i$ bits, wherein the characters to be represented are downloaded from memory in digital outline format, scaled, turned, and positioned to meet the text/image requirements, and the raster points lying on the outline of each character are determined using a scanning method (grid walk), **characterized** in that
before the beginning of a text display, only once are all characters of a text selected by the user rasterized into a fine raster, which in the x direction is $m$ times finer and in the y direction $n$ times finer than the display raster, where $m$ and $n$ are natural numbers greater than 1 and $m \times n \leq i$, and all rasterized characters are converted into a bitmap encoding and stored in buffer memory,
for text or image display, the fine-rasterized characters are downloaded from the buffer memory according to the text or image requirements and by their position in the text or image, are transferred into a corresponding fine-raster position in the display raster,
the bit values of the $m \times n$ fine-raster pixels in every display raster pixel of every character are written - as a bit sequence - in the memory location of the particular display raster pixel in the image repetition memory,

for image display, every display pixel memory location in the image repetition memory is read out and the particular display raster pixel is assigned a shade of gray that depends on the sum of the bit values of the read-out bit sequence, and is then represented on the display with an intensity that corresponds to the shade of gray.

3. The method according to claim 1 or 2, **characterized** in that a gray shade is assigned to every bit sequence by interpreting the bit sequence read out of the image repetition memory as an address and the pertaining gray shade with this address is read out from a look-up table prepared and stored in advance.

4. The method according to claim 1 or 2, **characterized** in that in the process of assigning the gray value, the bit values of the read-out bit sequence are summed up.

5. The method according to one of the preceding claims, **characterized** in that from white to black a total of ($m$ x $n$ + 1) gray values are used and the gray value of a display raster pixel is represented by the sum of the bit values of the fine raster.

6. The method according to one of the preceding claims, **characterized** in that the fine raster of every display raster pixel is written into the image repetition memory by logically associating the bit sequence with the content of the memory location in the image repetition memory corresponding to this display raster pixel in a bit by bit process using the logical OR association

7. The method according to one of the preceding claims, **characterized** in that the rasterization is performed in the fine raster without using an intelligent rasterization process with instructions in the outline format.

8. The method according to one of the preceding claims, **characterized** in that for the fine raster m = 8 and n = 4 is selected.

9. The method according to one of claims 1 to 7, **characterized** in that for the fine raster m = 4 and n = 4 is selected.

10. The method according to one of the preceding claims, **characterized** in that $m$ x $n < i$ and in the image repetition memory in every display raster pixel memory 1 bit is provided as a flag bit, which indicates whether the memory contains a bit sequence representing the fine raster of the display raster pixel or exclusively an encoding of the color of the display raster pixel.

11. The method according to one of the preceding claims, **characterized** in that with a bit depth of $i = j + 1 + m$ x $n$, where j is a natural number greater than 1, m x n bits for the storage of the fine raster, 1 bit is used and the remaining j bits serve to encode the color, which is to be represented in the display raster pixel with an intensity corresponding to the gray value.

12. A method used to output text and graphics on a printer according to one of the preceding claims of a method used to represent text and graphics on a color visual display unit, **characterized** in that the information related to the representation to be printed, which is stored in the image repetition memory, is used to directly control the printer without the interpretation of the page description and any new rasterization.